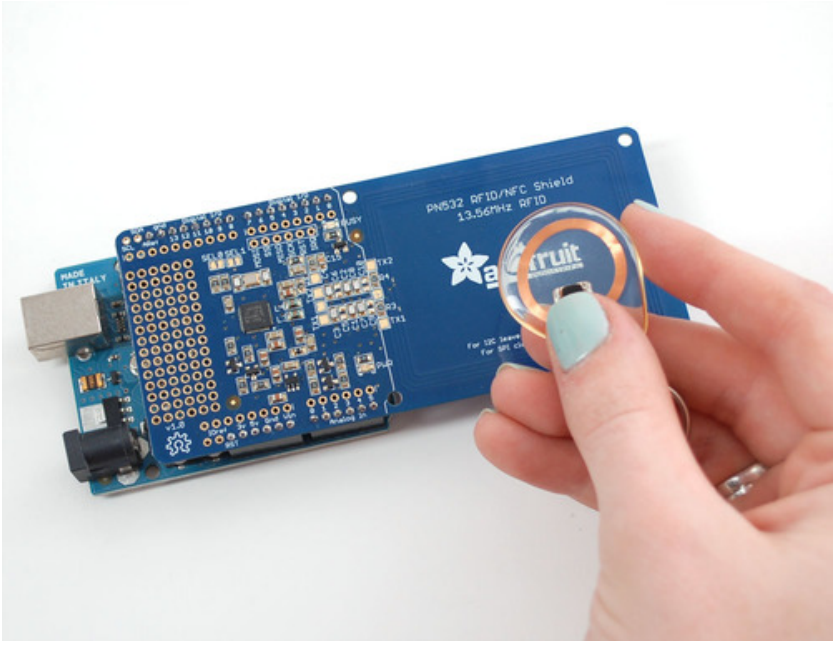
adafruit learning system

Adafruit PN532 RFID/NFC Breakout and Shield

Created by lady ada



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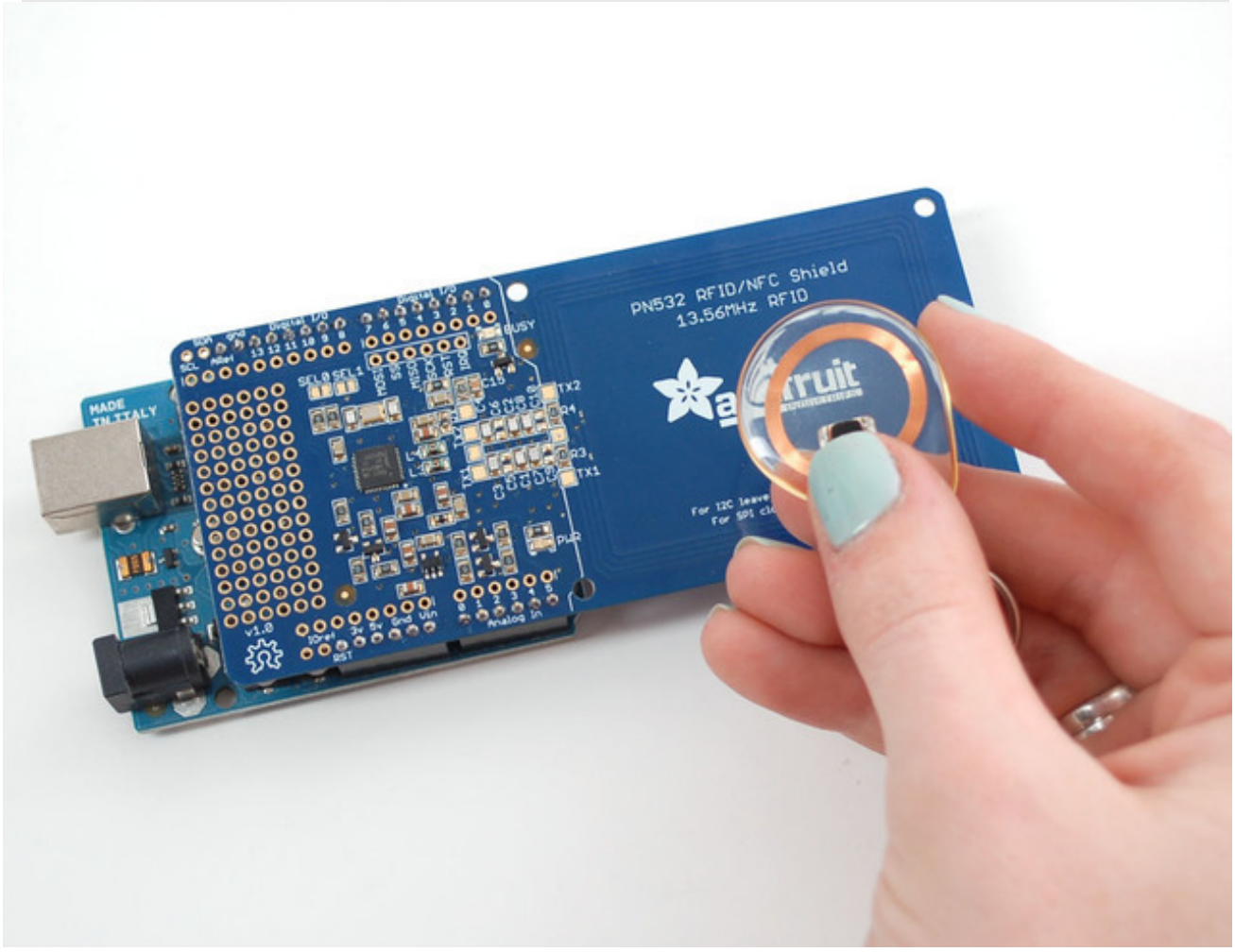
Overview

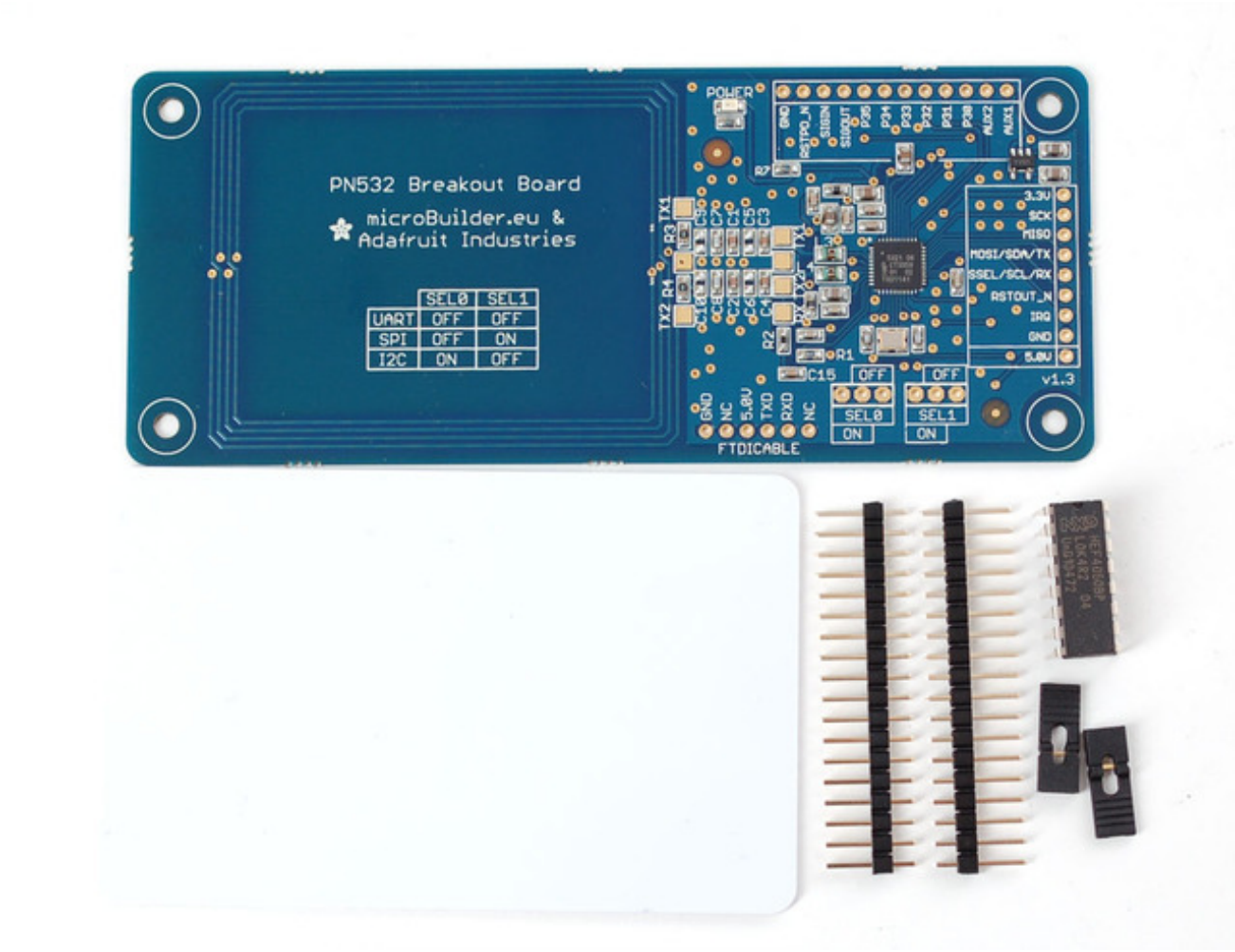


Hey! So this is not a full tutorial, its just a quickstart guide while we do more research into RFID/NFC. There's a lot of info here but not everything is explained in detail. We hope to fill out the tutorial but there's not a lot of good information about NFC so it's taking a bit of time!

Breakout Wiring

This part of the tutorial is specifically for the Breakout board. We show how to use it with SPI. The breakout also supports TTL serial and I2C but we don't have a tutorial for using it that way as SPI is the most cross-platform method to communicate

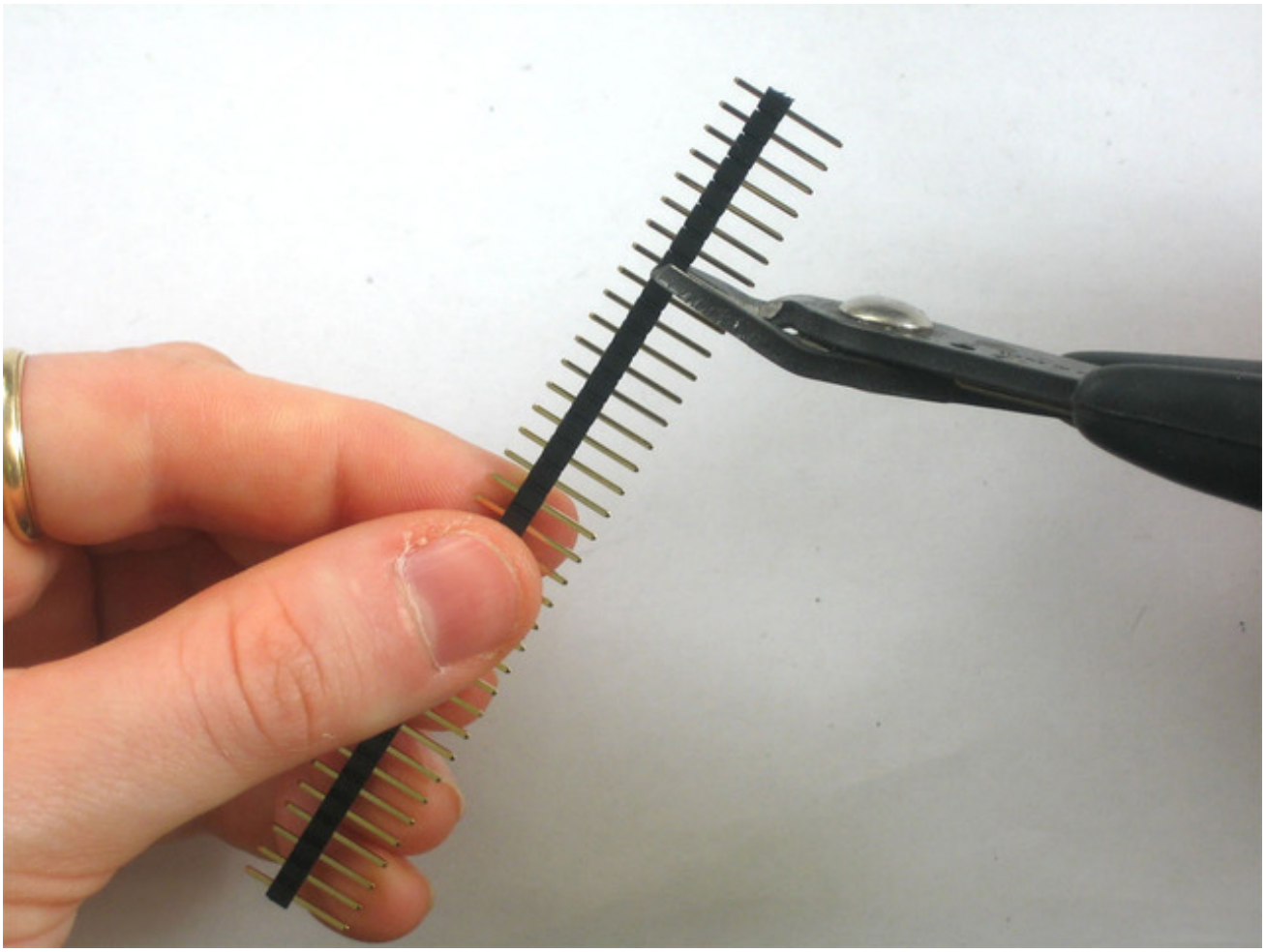
If you're using the shield, check the next page

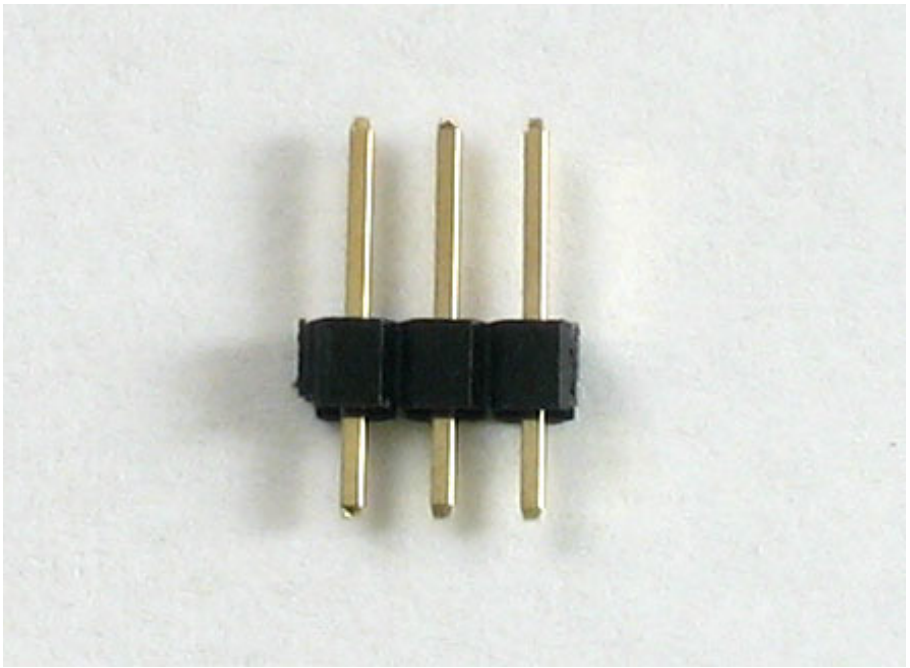


Wiring the Breakout for SPI

The PN532 chip and breakout is designed to be used by 3.3V systems. To use it with a 5V system such as an Arduino, a level shifter is required to convert the high voltages into 3.3V. If you have a 3.3V embedded system you won't have to use the shifter of course!

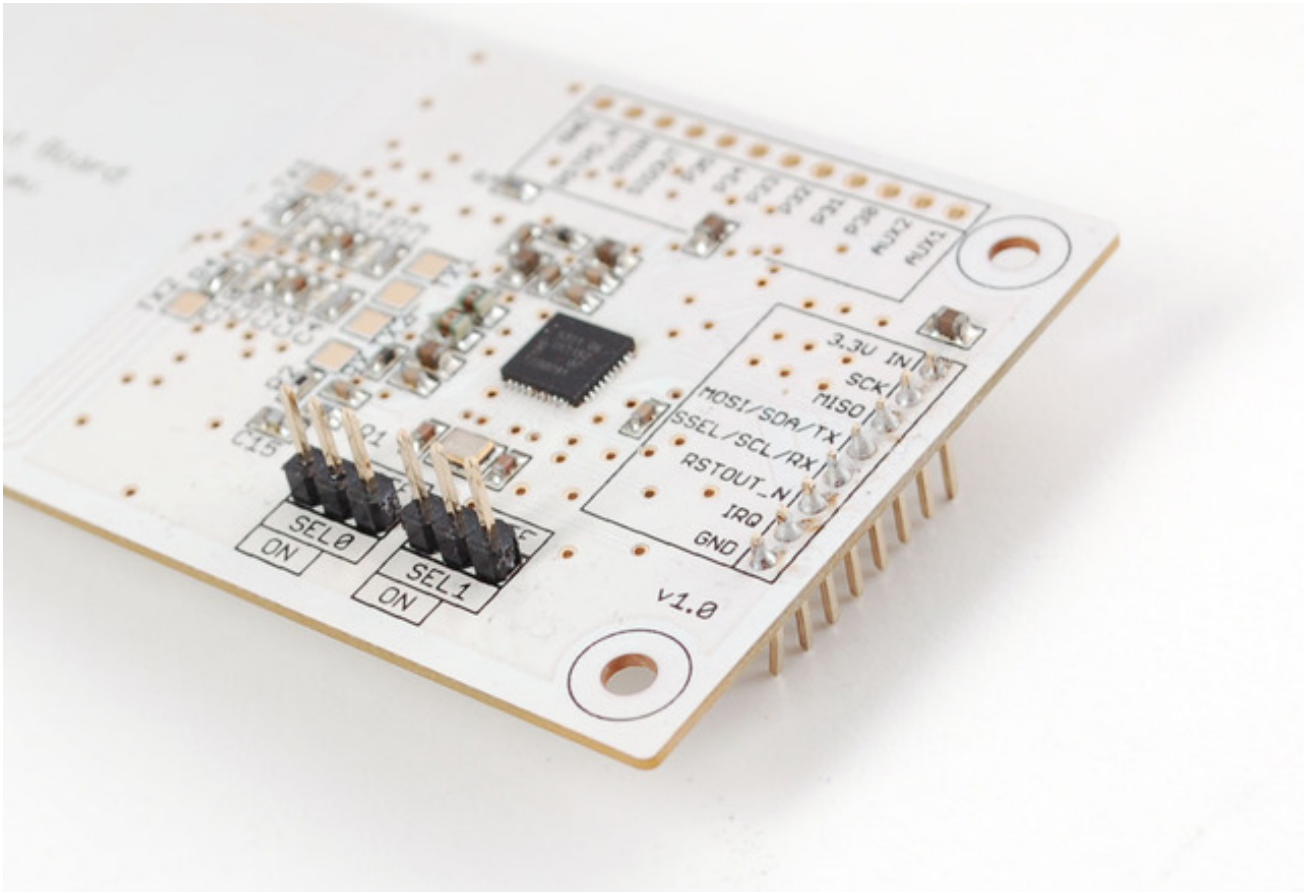
To begin, we'll solder in the header to the breakout board. You'll need two small 3-pin pieces of header and one 8-pin piece. You can break these off of a large piece.





Solder the two small pieces to the **SEL0** and **SEL1** pads. These are interface selectors for the chip. Depending on how the jumpers are inserted the chip will talk in TTL serial, i2c or

SPI. Also solder a strip to the end so you can plug it into a breadboard.



Wire up the 4050 level shifter chip to the Arduino as shown. The notch in the 4050 is at the 'top' in this image.

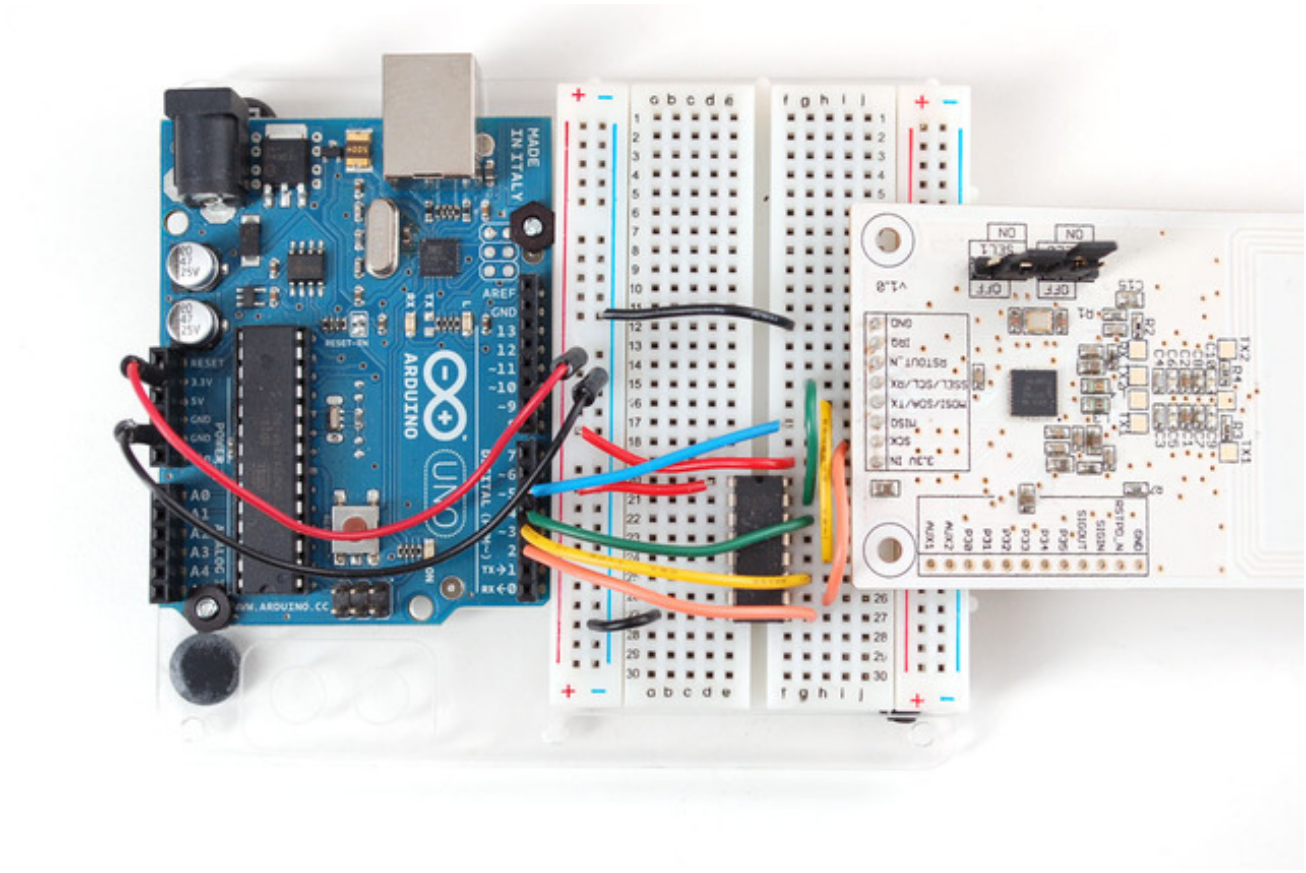
- Arduino digital pin **2** is connected to 4050 pin **9** (orange wire)
- Arduino digital pin **3** is connected to 4050 pin **11**(yellow wire)
- Arduino digital pin **4** is connected to 4050 pin **14** (green wire)

On the breakout board

- **3.3Vin** is connected to the Arduino **3.3V** pn
- **SCK** is connected to 4050 pin **10** (orange wire)
- **MISO** is connected to Arduino pin **5** (blue wire)
- **MOSI** is connected to 4050 pin **12** (yellow wire)
- **SSEL** is connected to 4050 pin **15&** (green wire)
- **GND** connects to Arduino **ground** (black wire)

Also connect 4050 pin #1 to **3.3V** and pin #8 to **ground**.

Click to see a larger image. The red power wire should be connected to the **3.3v** pin on the Arduino!



Also, we need to select SPI as the interface so on **SEL1** place the jumper in the **ON** position. for **SEL0** place the jumper in the **OFF** position.

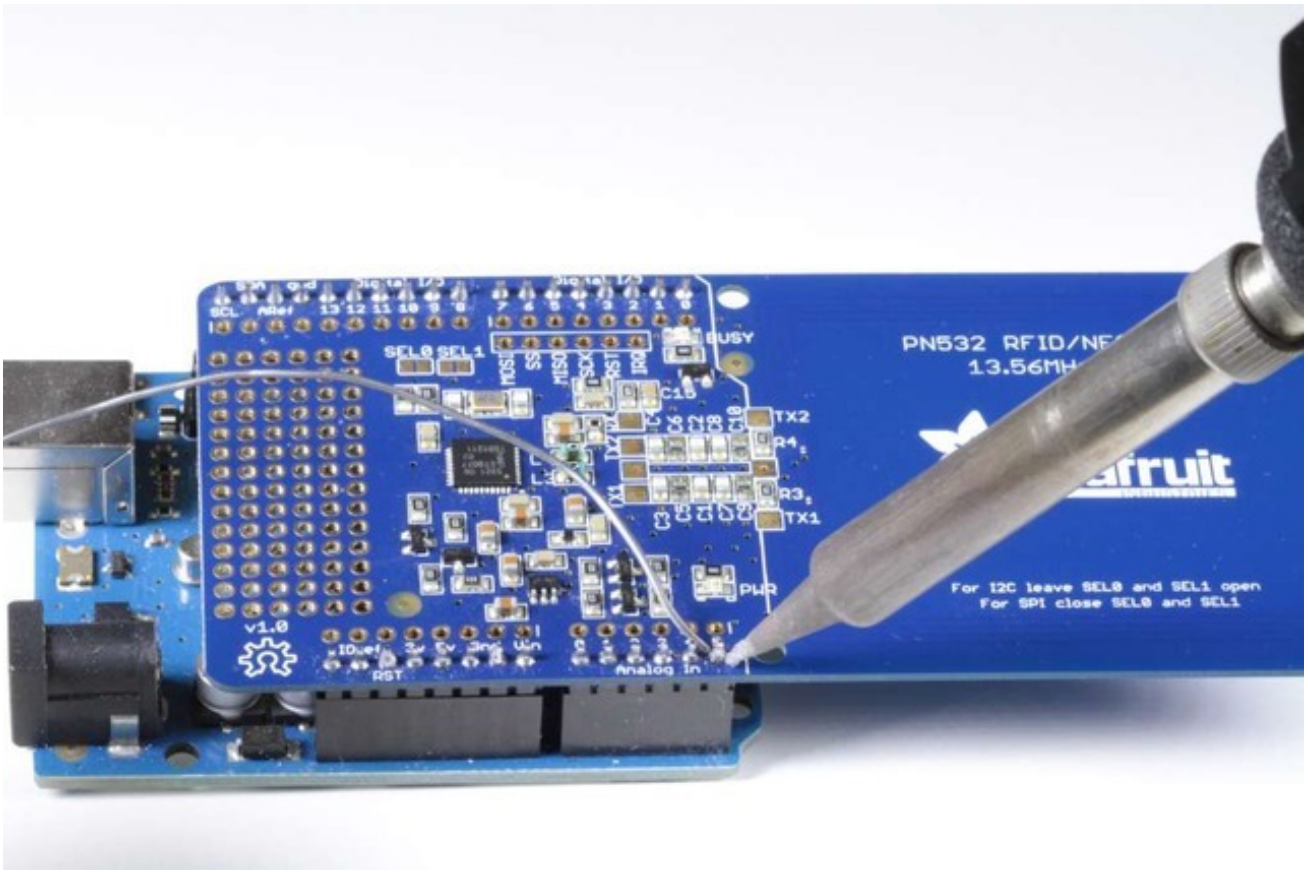
That's it! Later on you can change what Arduino pins you are using but for the beginning test we suggest matching our wiring.

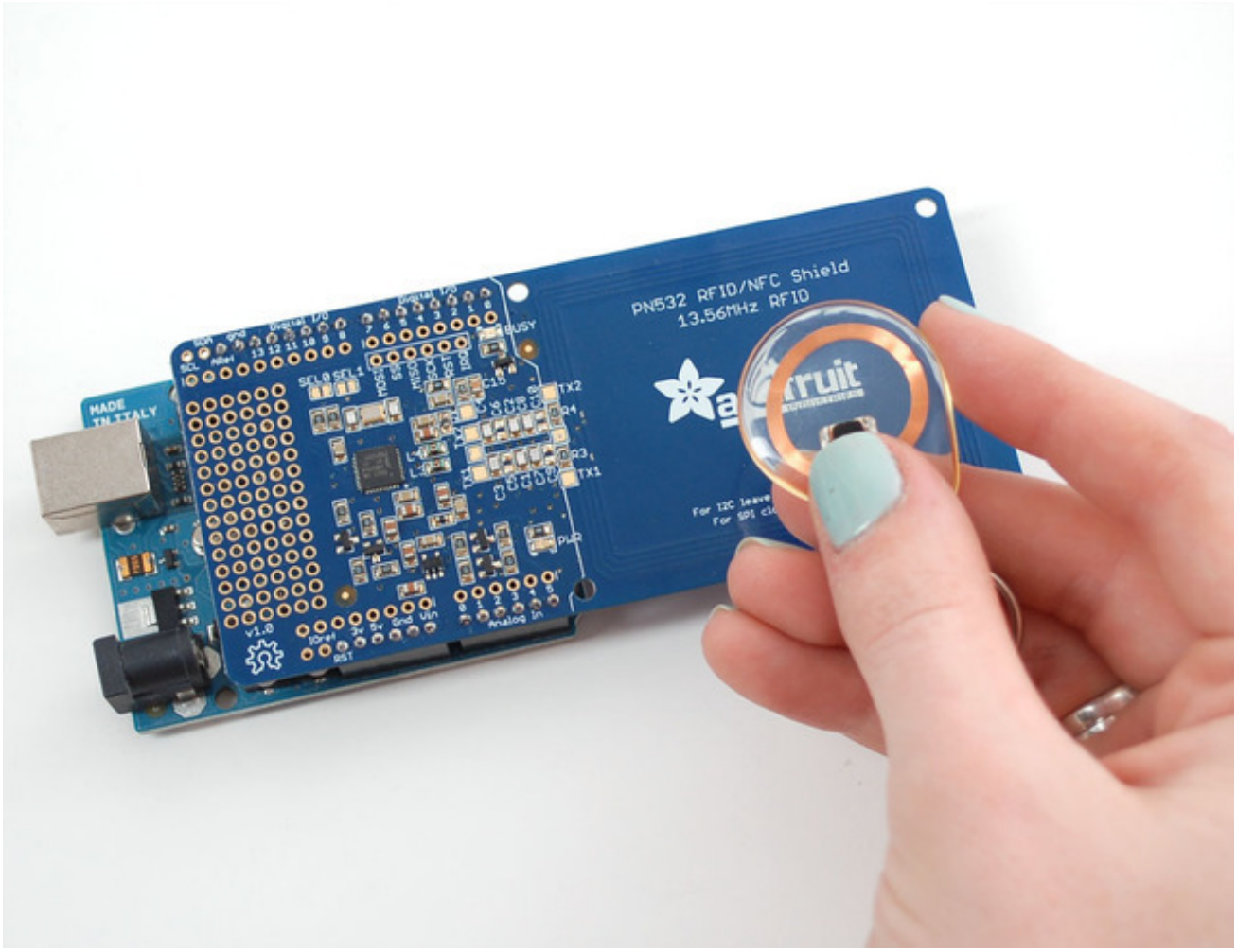
If you are using the shield in I2C mode, you will also need to add two 1.5K pullups on the SCL/SDA lines, since the breakout and the Arduino don't include the pullups. Simply solder or add a 1.5K resistor between SCL and 3.3V, and SDA and 3.3V, and then connect the breakout as you normally would.

Shield Wiring

Solder the Headers

The first step is to solder the headers to the shield. Cut the header strip to length and insert the sections (long pins down) into an Arduino. Then place the shield on top and solder each pin.





Using the Adafruit NFC Shield with I2C

The Adafruit NFC shield is designed to be used using the I2C by default. I2C only uses two pins (Analog 4 and 5 which are fixed in hardware and cannot be changed) to communicate and one pin as an 'interrupt' pin (Digital 2 - can be changed however). What is nice about I2C is that it is a 'shared' bus - unlike SPI and TTL serial - so you can put as many sensors as you'd like all on the same two pins, as long as their addresses don't collide/conflict. The Interrupt pin is handy because instead of constantly asking the NFC shield "is there a card in view yet? what about now?" constantly, the chip will alert us when a NFC target comes into the antenna range.

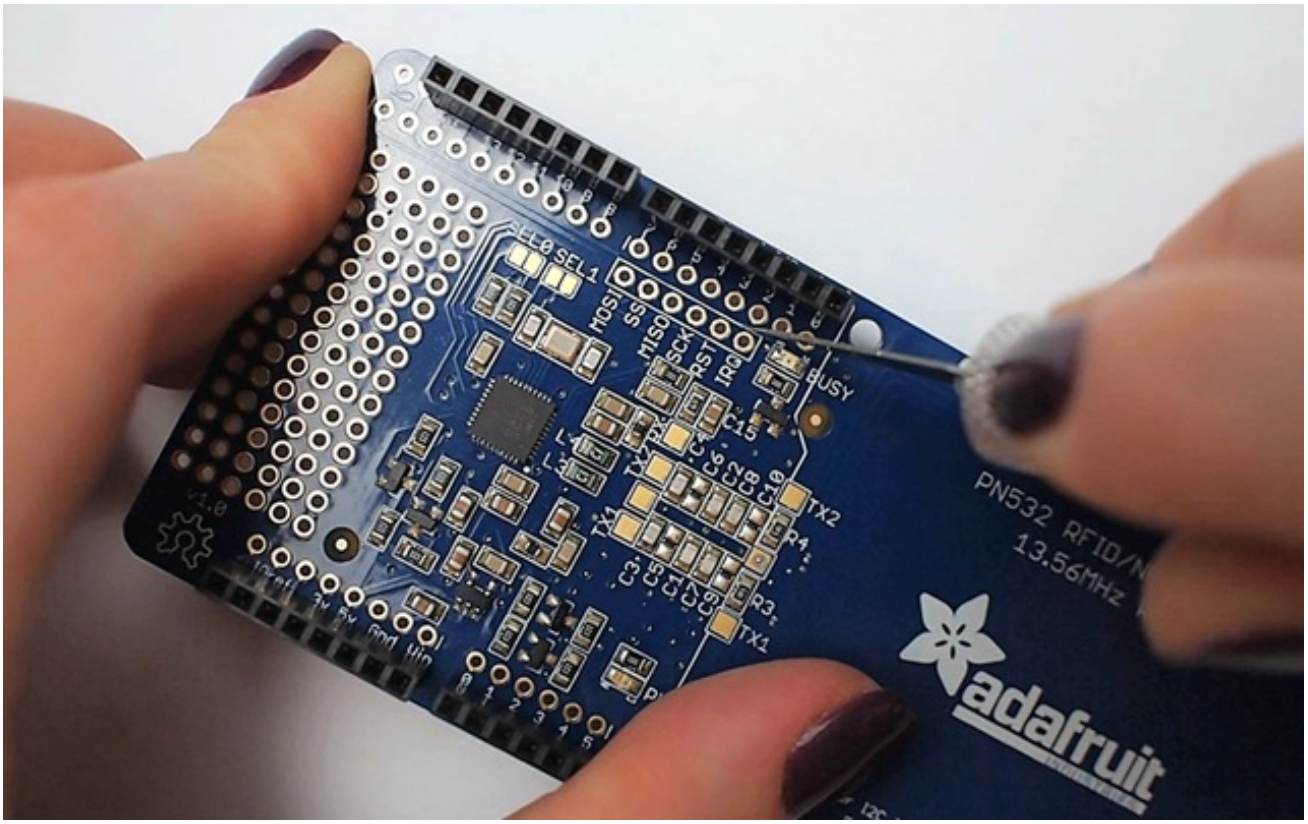
The shield is drop-in compatible with any Classic Arduino (UNO, Duemilanove, Diecimilla, etc using the ATmega168 or '328) as well as any Mega R3 or later.

Mega R2 Arduinos work as well but you need to solder a wire from the (http://adafru.it/aUS)**SDA (http://adafru.it/aUS)** and (http://adafru.it/aUS)**SCL (http://adafru.it/aUS)** pin holes to the Mega's I2C pins on Digital #20 and #21 (http://adafru.it/aUS)

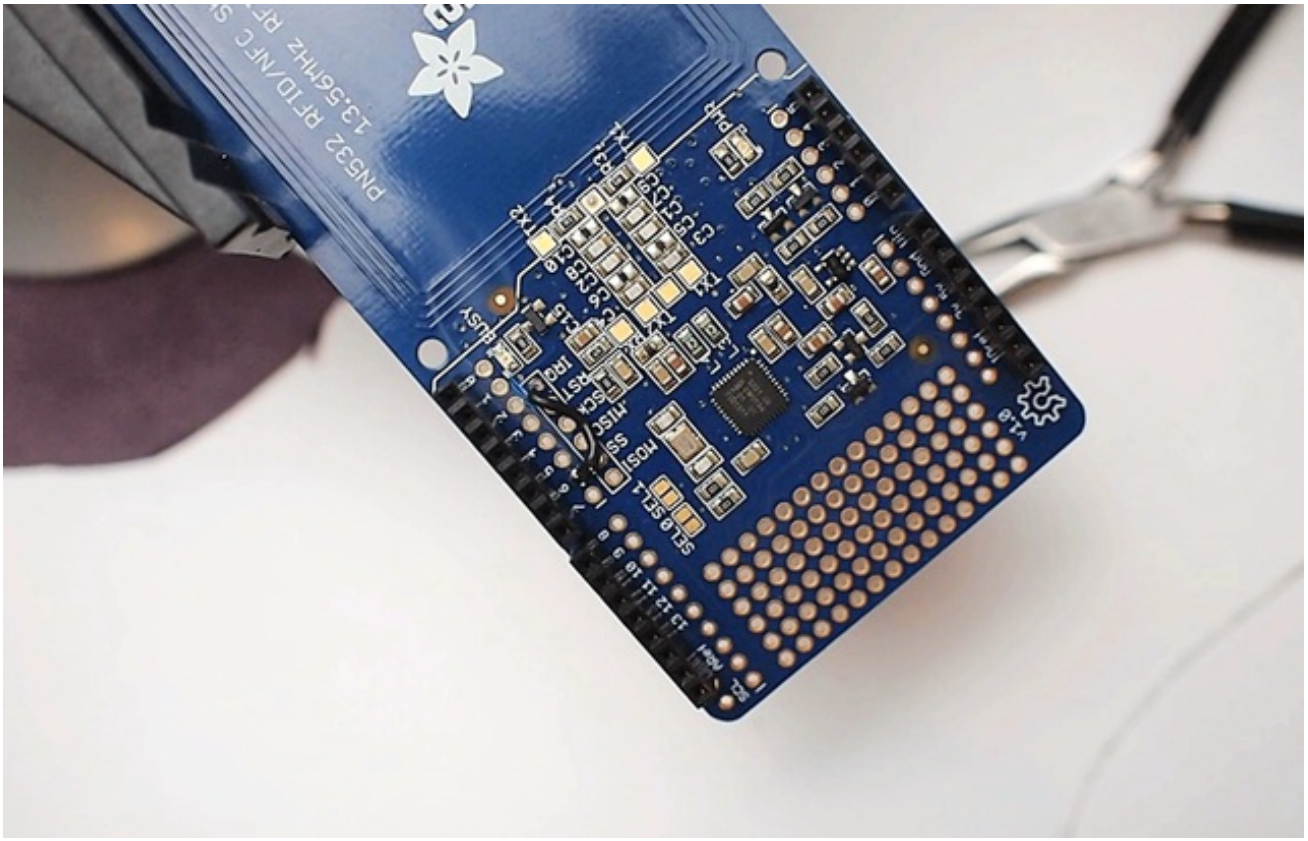
Using with the Arduino Leonardo and Yun

The IRQ pin is tied to Digital pin #2 by default. However, on the Arduino Leonardo and Yun, digital #2 is used for I2C which will not work. If using with a Leonardo or Yun, cut the trace beween the IRQ pin and Digital #2 and solder a wire from IRQ pin to Digital #4 or higher. Then change the example code so the the IRQ pin is declared as the new pin (say #6) not #2

Here are some photos of setting the IRQ pin to digital 6. First, use a sharp hobby knife to cut the trace from IRQ to 2



Solder a wire from IRQ to #6


PN532 RFID/NFC
13.56MHZ
V1.0

Arduino Library

Which Library?

We have two libraries (hopefully will be merged into one shortly) for the Adafruit NFC boards. One library is for SPI interfacing and one is for I2C. Both have the same functionality, capability and function names they just differ in whether they talk to the PN532 chip with I2C or with SPI. For the breakout, we assume you'll be using the SPI library. For the shield, we assume you'll be using the I2C library.

Both libraries have the ability to read MiFare cards, including the hard-coded ID numbers, as well as authenticate and read/write EEPROM chunks

I2C Library FOR USE WITH THE SHIELD ONLY

Download the PN532 I2C library from github (http://adafru.it/aSW). Uncompress the folder and rename the folder **Adafruit_NFCShield_I2C**. Inside the folder you should see the **Adafruit_NFCShield_I2C.cpp** and **Adafruit_NFCShield_I2C.h** files. Install the**Adafruit_NFCShield_I2C** library foler by placing it in your ***arduinosketchfolder*/libraries** folder. You may have to create the **libraries** subfolder if this is your first library. You can read more about installing libraries in our tutorial (http://adafru.it/aYG).

Restart the Arduino IDE. You should now be able to select **File > Examples > Adafruit_NFCShield_I2C > readMifare** sketch. Upload the sketch to your Arduino with the shield plugged in.

SPI Library FOR USE WITH THE BREAKOUT BOARD ONLY

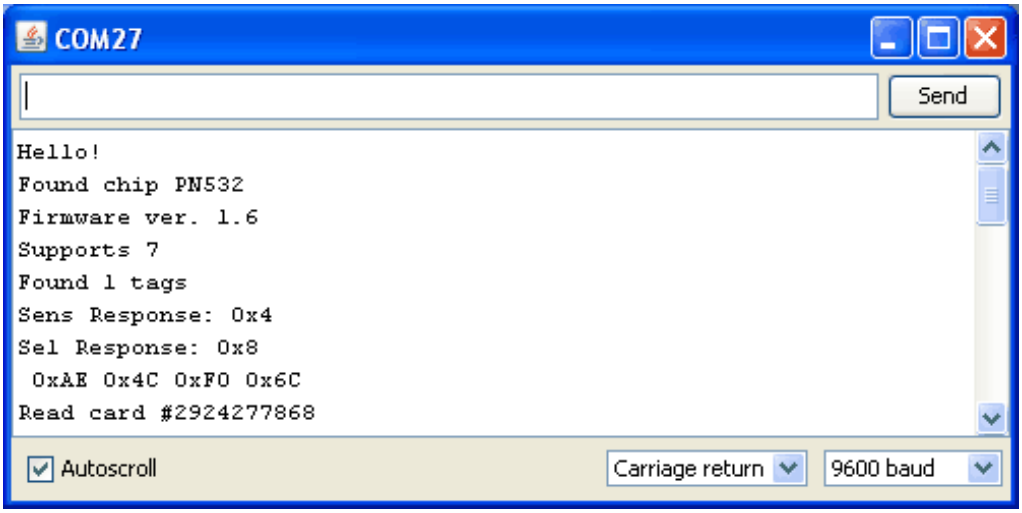
Download the PN532 SPI library from github (http://adafru.it/aSX). Uncompress the folder and rename the folder **Adafruit_PN532**. Inside the folder you should see the **Adafruit_PN532.cpp** and **Adafruit_PN532.h** files. Install the **Adafruit_PN532** library foler by placing it in your ***arduinosketchfolder*/libraries** folder. You may have to create the **libraries** subfolder if this is your first library. You can read more about installing libraries in our tutorial (http://adafru.it/aYG).

Restart the Arduino IDE. You should now be able to select **File > Examples > Adafruit_PN532 > readMifare** sketch. Upload the sketch to your Arduino wired as in our tutorial

Testing MiFare

In the serial monitor, you should see that it found the **PN532** chip. Then you can place your tag nearby and it will display the 4 byte ID code (this one is 0xAE 0x4C 0xF0 0x6C) and then the integer version of all four bytes together. You can use this number to identify each card. Recently NXP made so many cards that they actually ran through all 4 Bytes (2^32) so the number is not guaranteed to be absolutely unique. However, the chances are extremely slim

you will have two cards with the same ID so as long as you aren't using these cards for anything terribly important (like money transfer) its fine to use the number as a unique identifier



About NFC

NFC (Near Field Communication)

NFC (Near Field Communication) is a set of short-range (typically up to 10cm) wireless communication technologies designed to offer light-weight and secure communication between two devices. While NFC was invented by NXP (Phillips at the time), Nokia and Sony, the main body behind the NFC 'standard' today is the NFC Forum (http://adafru.it/aSy), who are responsible for publishing and maintaining a variety of standards relating to NFC technology.

NFC operates at 13.56MHz, and is based around an "initiator" and "target" model where the initiator generates a small magnetic field that powers the target, meaning that the target does not require a power source. This means of communication is referred to as **Passive Communication**, and is used to read and write to small, inexpensive 13.56MHz RFID tags based on standards like ISO14443A. **Active communication** (peer-to-peer) is also possible when both devices are powered, where each device alternately creates its own magentic field, with the secondary device as a target and vice versa in continuous rotation.

Passive Communication: ISO14443A Cards (Mifare, etc.)

While the PN53x family of transceivers from NXP are compatible with a number of 13.56MHz RFID card standards, by far the most popular standard is ISO14443A. A variety of manufacturers produce ISO14443A compatible cards or chips, but the most common are based around the **Mifare** family from NXP. Mifare Classic and Mifare Ultralight are probably the most frequently encountered and useful for basic projects, though many tags with improved security and encryption also exist (Mifare DESFire, etc.). All of the tags sold at adafruit.com are Mifare Classic 1K, meaning that they contains 1K (1024 bytes) of programmable EEPROM memory which can be read and modified in passive mode by the initiator device (the PN532).

While all ISO14443A cards share certain common characteristics on the highest level (defined by the four part standard), each set of Mifare chips (Classic, Ultralight, Plus, DESFire, etc.) has it's own features and peculiarities. The two most common formats are described below.

- Mifare Classic (http://adafru.it/cl7): These cards are extremely common, and contain 1K or 4K of EEPROM, with basic security for each 64 byte (1K/4K cards) or 256 byte (4K cards) sector.
- Mifare Ultralight (http://adafru.it/cl7): Contains 512 bytes of EEPROM, including 32-bits of OTP memory. These tags are inexpensive, often come in sticker format and are are frequently used for transportation ticketing, concert tickets, etc.

Active Communication (Peer-to-Peer)

Active or "Peer-to-Peer" communication is still based around the Initiator/Target model described earlier, but both devices are actively powered and switch roles from being an

Initiator or a Target during the communication. When one device is initiating a conversation with the other, it enables it's magnetic field and the receiving device listens in (with it's own magnetic field disabled). Afterwards, the target/recipient device may need to respond and will in turn activate it's own magnetic field and the original device will be configured as the target. Despite two devices being present, only one magnetic field is active at a time, with each device constantly enabling or disabling its own magnetic field.

ToDo: Add better description of active mode, but I need to test it out a bit first myself!

NFC Data Exchange Format (NDEF)

The NFC Data Exchange Format (NDEF) is a standardised data format that can be used to exchange information between any compatible NFC device and another NFC device or tag. The data format consists of **NDEF Messages** and **NDEF Records**. The standard is maintained by the NFC Forum and is freely available for consultation but requires accepting a license agreement to download (http://adafru.it/aSA).

The NDEF format is used to store and exchange information like URIs, plain text, etc., using a commonly understood format. NFC tags like Mifare Classic cards can be configured as NDEF tags, and data written to them by one NFC device (NDEF Records) can be understood and accessed by any other NDEF compatible device. NDEF messages can also be used to exchange data between two active NFC devices in "peer-to-peer" mode. By adhering to the NDEF data exchange format during communication, devices that would otherwise have no meaningful knowledge of each other or common language are able to share data in an organised, mutually understandable manner.

The NDEF standard includes numerous **Record Type Definitions (RTDs)** that define how information like URIs should be stored, and each NDEF device, tag or message can contained multiple RTDs. Standard RTD definitions are described in "NFC Record Type Definition (RTD) Specification" maintained by the NFC Forum.

* NDEF Overview (http://adafru.it/cl7): This page offers a more detailed explanation of NDEF, including how Mifare Classic cards can be used to store NDEF messages.

NOTE: The dedicated NDEF page is still a work in progress and some information is currently incomplete.

Reading

For more details about NFC/RFID and this chip we suggest the following fantastic resources:

- RFID selection guide (http://adafru.it/aSC) - a lot of details about RFID in general
- Nokia's Introduction to NFC (http://adafru.it/aSD)- a lot of details about NFC in general
- NXP S50 chip datasheet (http://adafru.it/aSE) , the chip *inside* MiFare classic tags
- NXP PN532 Short Form Datasheet (http://adafru.it/aSF)
- NXP PN532 Long Form Datasheet (http://adafru.it/aSG)
- NXP PN532 User Manual (http://adafru.it/aSH)

- NXP PN532 App Note (http://adafru.it/aSI)
- Using PN532 with libnfc (http://adafru.it/aSJ)
- NFC Glossary (http://adafru.it/aSK)

MiFare Cards & Tags

MiFare is one of the four 13.56MHz card 'protocols' (FeliCa is another well known one) All of the cards and tags sold at the Adafruit shop use the inexpensive and popular MiFare Classic chipset

MiFare Classic Cards

MIFARE Classic cards come in 1K and 4K varieties. While several varieties of chips exist, the two main chipsets used are described in the following publicly accessible documents:

- MF1S503x Mifare Classic 1K data sheet (http://adafru.it/aSL)
- MF1S70yyX MIFARE Classic 4K data sheet (http://adafru.it/aSM)

Mifare Classic cards typically have a **4-byte NUID** that uniquely (within the numeric limits of the value) identifies the card. It's possible to have a 7 byte IDs as well, but the 4 byte models are far more common for Mifare Classic.

EEPROM Memory

Mifare Classic cards have either 1K or 4K of EEPROM memory. Each memory block can be configured with different access conditions, with two seperate authentication keys present in each block.

Mifare Classic cards are divided into section called **sectors** and **blocks**. Each "sector" has individual access rights, and contains a fixed number of "blocks" that are controlled by these access rights. Each block contains 16 bytes, and sectors contains either 4 blocks (1K/4K cards) for a total of 64 bytes per sector, or 16 blocks (4K cards only) for a total of 256 bytes per sector. The card types are organised as follows:

- **1K Cards** - 16 sectors of 4 blocks each (sectors 0..15)
- **4K Cards** - 32 sectors of 4 blocks each (sectors 0..31) and 8 sectors of 16 blocks each (sectors 32..39)

4 Block Sectors

1K and 4K cards both use 16 sectors of 4 blocks each, with the bottom 1K of memory on the 4K cards being organised identically to the 1K models for compatability reasons. These individual 4 block sectors (containing 64 byts each) have basic security features are can each be configured with seperate read/write access and two different 6-byte authentication keys (the keys can be different for each sector). Due to these security features (which are stored in the last block, called the **Sector Trailer**), only the bottom 3 blocks of each sector are actually available for data storage, meaning you have 48 bytes per 64 byte sector available for your own use.

Each 4 block sector is organised as follows, with four rows of 16 bytes each for a total of 64-bytes per sector. The first two sectors of any card are shown:

Sector	Block	Bytes	Description

```
------ -----  -----                                  -----------
         0  1  2  3  4  5  6  7  8  9  10 11 12 13 14 15
```

```
1    3    [-------KEY A-------]  [Access Bits]  [-------KEY B-------]  Sector Trailer
     2    [                    Data                    ]  Data
     1    [                    Data                    ]  Data
     0    [                    Data                    ]  Data
```

```
0    3    [-------KEY A-------]  [Access Bits]  [-------KEY B-------]  Sector Trailer
     2    [                    Data                    ]  Data
     1    [                    Data                    ]  Data
     0    [               Manufacturer Data                ]  Manufacturer Block
```

Sector Trailer (Block 3)
The sector trailer block contains the two secret keys (Key A and Key B), as well as the access conditions for the four blocks. It has the following structure:

```
   Sector Trailer Bytes
   -----------------------------------------------------------
   0  1  2  3  4  5  6  7  8  9  10 11 12 13 14 15
   [     Key A     ] [Access Bits] [     Key B     ]
```

For more information in using Keys to access the clock contents, see Accessing Data Blocks further below.

Data Blocks (Blocks 0..2)
Data blocks are 16 bytes wide and, depending on the permissions set in the access bits, can be read from and written to. You are free to use the 16 data bytes in any way you wish. You can easily store text input, store four 32-bit integer values, a 16 character uri, etc.

Data Blocks as "Value Blocks"
An alternative to storing random data in the 16 byte-wide blocks is to configure them as "Value Blocks". Value blocks allow performing electronic purse functions (valid commands are: read, write, increment, decrement, restore, transfer).

Each Value block contains a single signed 32-bit value, and this value is stored 3 times for data integrity and security reasons. It is stored twice non-inverted, and once inverted. The last 4 bytes are used for a 1-byte address, which is stored 4 times (twice non-inverted, and twice inverted).

Data blocks configured as "Value Blocks" have the following structure:

```
Value Block Bytes
-------------------------------------------------------------
0  1  2  3  4  5  6  7  8  9  10 11 12 13 14 15
[  Value  ] [  ~Value ] [  Value  ] [A  ~A  A   ~A]
```

Manufacturer Block (Sector 0, Block 0)
Sector 0 is special since it contains the Manufacturer Block. This block contains the manufacturer data, and is read-only. It should be avoided unless you know what you are doing.

16 Block Sectors

16 block sectors are identical to 4 block sectors, but with more data blocks. The same structure described in the 4 block sectors above applies.

```
Sector  Block   Bytes                                   Description
------ -----  -----                                  ----------
          0  1  2  3  4  5  6  7  8  9  10 11 12 13 14 15
```

```
32    15    [-------KEY A-------]  [Access Bits]  [-------KEY B-------]  Sector Trailer 32
      14    [                  Data                  ]  Data
      13    [                  Data                  ]  Data
      ...
      2     [                  Data                  ]  Data
      1     [                  Data                  ]  Data
      0     [                  Data                  ]  Data
```

Accessing EEPROM Memory

To access the EEPROM on the cards, you need to perform the following steps:

1. You must retrieve the 4-byte NUID of the card (this can sometimes be 7-bytes long as well, though rarely for Mifare Classic cards). This is required for the subsequent authentication process.
2. You must authenticate the sector you wish to access according to the access rules defined in the Sector Trailer block for that sector, by passing in the appropriate 6 byte Authentication Key (ex. 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF for new cards).
3. Once authenication has succeeded, and depending on the sector permissions, you can then read/write/increment/decrement the contents of the specific block. Note that you need to re-authenticate for each sector that you access, since each sector can have it's own distinct access keys and rights!

Note on Authentication

Before you can do access the sector's memory, you first need to "authenticate" according

to the security settings stored in the Sector Trailer. By default, any new card will generally be configured to allow full access to every block in the sector using Key A and a value of 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF. Some other common keys that you may wish to try if this doesn't work are:

```
0XFF 0XFF 0XFF 0XFF 0XFF 0XFF
0XD3 0XF7 0XD3 0XF7 0XD3 0XF7
0XA0 0XA1 0XA2 0XA3 0XA4 0XA5
0XB0 0XB1 0XB2 0XB3 0XB4 0XB5
0X4D 0X3A 0X99 0XC3 0X51 0XDD
0X1A 0X98 0X2C 0X7E 0X45 0X9A
0XAA 0XBB 0XCC 0XDD 0XEE 0XFF
0X00 0X00 0X00 0X00 0X00 0X00
0XAB 0XCD 0XEF 0X12 0X34 0X56
```

Example of a New Mifare Classic 1K Card

The follow memory dump illustrates the structure of a 1K Mifare Classic Card, where the data and Sector Trailer blocks can be clearly seen:

```
[--------------------------Start of Memory Dump--------------------------]
------------------------Sector 0------------------------
Block 0  8E 02 6F 66 85 08 04 00 62 63 64 65 66 67 68 69  ?.of?...bcdefghi
Block 1  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 2  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 3  00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
------------------------Sector 1------------------------
Block 4  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 5  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 6  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 7  00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
------------------------Sector 2------------------------
Block 8  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 9  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 10 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 11 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
------------------------Sector 3------------------------
Block 12 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 13 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 14 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 15 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
------------------------Sector 4------------------------
Block 16 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 17 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 18 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
```

```
Block 19 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
-----------------------Sector 5-----------------------
Block 20 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 21 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 22 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 23 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
-----------------------Sector 6-----------------------
Block 24 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 25 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 26 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 27 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
-----------------------Sector 7-----------------------
Block 28 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 29 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 30 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 31 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
-----------------------Sector 8-----------------------
Block 32 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 33 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 34 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 35 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
-----------------------Sector 9-----------------------
Block 36 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 37 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 38 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 39 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
-----------------------Sector 10-----------------------
Block 40 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 41 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 42 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 43 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
-----------------------Sector 11-----------------------
Block 44 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 45 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 46 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 47 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
-----------------------Sector 12-----------------------
Block 48 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 49 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 50 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 51 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
-----------------------Sector 13-----------------------
Block 52 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 53 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 54 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 55 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
-----------------------Sector 14-----------------------
```

```
Block 56 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 57 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 58 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 59 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
-----------------------Sector 15-----------------------
Block 60 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 61 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 62 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 63 00 00 00 00 00 00 FF 07 80 69 FF FF FF FF FF FF  ......ÿ.?iÿÿÿÿÿÿ
[---------------------------End of Memory Dump---------------------------]
```

MiFare Ultralight Cards

MiFare Ultralight cards typically contain 512 bits (64 bytes) of memory, including 4 bytes (32-bits) of OTP (One Time Programmable) memory where the individual bits can be written but not erased.

MF0ICU1 MiFare Ultralight Functional Specification (http://adafru.it/aSN)

MiFare Ultralight cards have a **7-byte UID** that uniquely identifies the card.

EEPROM Memory

MiFare Ultralight cards have 512 bits (64 bytes) of EEPROM memory, including 4 byte (32 bits) of OTP memory. Unlike Mifare Classic cards, there is no authentication on a per block level, although the blocks can be set to "read-only" mode using Lock Bytes (described below).

EEPROM memory is organised into 16 pages of four bytes eachs, in the following order:

```
Page   Description
----   ------------
0      Serial Number (4 bytes)
1      Serial Number (4 bytes)
2      Byte 0:    Serial Number
       Byte 1:    Internal Memory
       Byte 2..3: lock bytes
3      One-time programmable memory (4 bytes)
4..15  User memory (4 bytes)
```

Here are the pages and blocks arranged in table format:

```
Page   Block 0    Block 1    Block 2   Block 3
-----  ---------------------------------------
0      [          Serial Number          ]
```

```
1    [          Serial Number          ]
2    [Serial] - [Intern] - [   Lock Bytes  ]
3    [    One Time Programmable Memory     ]
4    [            User Data            ]
5    [            User Data            ]
6    [            User Data            ]
7    [            User Data            ]
8    [            User Data            ]
9    [            User Data            ]
10   [            User Data            ]
11   [            User Data            ]
12   [            User Data            ]
13   [            User Data            ]
14   [            User Data            ]
15   [            User Data            ]
```

Lock Bytes (Page 2)

Bytes 2 and 3 of page 2 are referred to as "Lock Bytes". Each page from 0x03 and higher can individually locked by setting the corresponding locking bit to "1" to prevent further write access, effectively making the memory read only.

For more information on the lock byte mechanism, refer to section 8.5.2 of the datasheet (referenced above).

OTP Bytes (Page 3)

Page 3 is the OTP memory, and by default all bits on this page are set to 0. These bits can be bitwise modified using the MiFare WRITE command, and individual bits can be set to 1, but can not be changed back to 0.

Data Pages (Page 4-15)

Pages 4 to 15 are can be freely read from and written to, provided there is no conflict with the Lock Bytes described above.

After production, the bytes have the following default values:

```
Page    Byte Values
----    -----------------------
        0    1    2    3
4       0xFF 0xFF 0xFF 0xFF
5..15   0x00 0x00 0x00 0x00
```

Accessing Data Blocks

In order to access the cards, you must following two steps:

1. 'Connect' to a Mifare Ultralight card and retrieve the 7 byte UID of the card.
2. Memory can be read and written directly once a passive mode connection has been made. No authentication is required for Mifare Ultralight cards.

Read/Write Lengths

For compatability reasons, "Read" requests to a Mifare Ultralight card will retrieve 16 bytes (4 pages) at a time (which corresponds to block size of a Mifare Classic card). For example, if you specify that you want to read page 3, in reality pages 3, 4, 5 and 6 will be read and returned, and you can simply discard the last 12 bytes if they aren't needed. If you select a higher page, the 16 byte read will wrap over to page 0. For example, reading page 14 will actually return page 14, 15, 0 and 1.

"Write" requests occur in pages (4 bytes), so there is no problem with overwriting data on subsequent pages.

About the NDEF Format

NDEF (NFC Data Exchange Format)

The NFC Data Exchange Format (NDEF) is a standardised data format that can be used to exchange information between any compatible NFC device and another NFC device or tag. The data format consists of **NDEF Messages** and **NDEF Records**. The standard is maintained by the NFC Forum and is freely available for consultation but requires accepting a license agreement to download (http://adafru.it/aSA).

The NDEF format is used to store and exchange information like URIs, plain text, etc., using a commonly understood format. NFC tags like Mifare Classic cards can be configured as NDEF tags, and data written to them by one NFC device (NDEF Records) can be understood and accessed by any other NDEF compatible device. NDEF messages can also be used to exchange data between two active NFC devices in "peer-to-peer" mode. By adhering to the NDEF data exchange format during communication, devices that would otherwise have no meaningful knowledge of each other or common language are able to share data in an organised, mutually understandable manner.

Some helpful app notes and white papers relating to NDEF are listed below:

- NFC Data Exchange Format (NDEF) Technical Specification (http://adafru.it/aSA) (requires accepting the license terms)
- NFC Record Type Definition (RTD) Specification (http://adafru.it/aSA) (requires accepting the license terms)
- NXP White Paper - NFC Forum Type Tags (http://adafru.it/aSO)

NDEF Messages

NDEF Messages are the basic "transportation" mechanism for NDEF records, with each message containing one or more NDEF Records.

NDEF Records

NDEF Records contain a specific payload, and have the following structure that identifies the contents and size of the record:

```
Bit 7   6    5    4    3    2    1    0
------ ------ ------ ------ ------ ------ ------ ------
[ MB ] [ ME ] [ CF ] [ SR ] [ IL ] [     TNF      ]

[                TYPE LENGTH                ]

[               PAYLOAD LENGTH                ]

[                ID LENGTH                 ]
```

```
[                  RECORD TYPE                  ]

[                     ID                     ]

[                  PAYLOAD                   ]
```

Record Header (Byte 0)

The record header contains a number of important fields, including a 3-bit field that identifies the type of record that follows (the **Type Name Format** or TNF):

TNF: Type Name Format Field

The Type Name Format or **TNF Field** of an NDEF record is a 3-bit value that describes the record type, and sets the expectation for the structure and content of the rest of the record. Possible record type names include:

```
TNF Value    Record Type
---------    -----------------------------------------
0x00         Empty Record
             Indicates no type, id, or payload is associated with this NDEF Record.
             This record type is useful on newly formatted cards since every NDEF tag
             must have at least one NDEF Record.

0x01         Well-Known Record
             Indicates the type field uses the RTD type name format.  This type name is used
             to stored any record defined by a Record Type Definition (RTD), such as storing
             RTD Text, RTD URIs, etc., and is one of the mostly frequently used and useful
             record types.

0x02         MIME Media Record
             Indicates the payload is an intermediate or final chunk of a chunked NDEF Record

0x03         Absolute URI Record
             Indicates the type field contains a value that follows the absolute-URI BNF
             construct defined by RFC 3986

0x04         External Record
             Indicates the type field contains a value that follows the RTD external
             name specification

0x05         Unknown Record
             Indicates the payload type is unknown

0x06         Unchanged Record
             Indicates the payload is an intermediate or final chunk of a chunked NDEF Record
```

IL: ID LENGTH Field
The IL flag indicates if the ID Length Field is preent or not. If this is set to 0, then the ID Length Field is ommitted in the record.

SR: Short Record Bit
The SR flag is set to one if the PAYLOAD LENGTH field is 1 byte (8 bits/0-255) or less. This allows for more compact records.

CF: Chunk Flag
The CF flag indicates if this is the first record chunk or a middle record chunk.

ME: Message End
The ME flag indicates if this is the last record in the message.MB: Message BeginThe MB flag indicates if this is the start of an NDEF message.

Type Length
Indicates the length (in bytes) of the Record Type field. This value is always zero for certain types of records defined with the TNF Field described above.

Payload Length
Indicates the length (in bytes) of the record payload. If the SR field (described above) is set to 1 in the record header, this value will be one byte long (for a payload length from 0-255 bytes). If the SR field is set to 0, this value will be a 32-bit value occupying 4 bytes.

ID Length
Indicates the length in bytes of the ID field. This field is present only if the IL flag (described above) is set to 1 in the record header.

Record Type
This value describes the 'type' of record that follows. The values of the type field must corresponse to the value entered in the TNF bits of the record header.

Record ID
The value of the ID field if an ID is included (the IL bit in the record header is set to 1). If the IL bit is set to 0, this field is ommitted.

Payload
The record payload, which will be exactly the number of bytes described in the Payload Length field earlier.

Well-Known Records (TNF Record Type 0x01)

Probably the most useful record type is the **"NFC Forum Well-Known Type"** (TNF Type 0x01). Record types that adhere to the "Well-Defined" type are each described by something called an RTD or **Record Type Definition**. Some of the current Well-Defined RTDs are:

URI Records (0x55/'U')

The "Well Known Type" for a URI record is 0x55 ('U'), and this record type can be used to store a variety of useful information such as telephone numbers (tel:), website addresses, links to FTP file locations, etc.

URI Records are defined in the document "URI Record Type Definition" from the NFC Forum, and it has the following structure:

Name	Offset	Size	Description
Identifier Code	0	1 byte	See table below
URI Field	1	N bytes	The rest of the URI (depending on byte 0 above)

The **URI Identifier Code** is use to shorten the URI length, and can have any of the following values:

Value	Protocol
0x00	No prepending is done ... the entire URI is contained in the URI Field
0x01	http://www.
0x02	https://www.
0x03	http://
0x04	https://
0x05	tel:
0x06	mailto:
0x07	ftp://anonymous:anonymous@
0x08	ftp://ftp.
0x09	ftps://
0x0A	sftp://
0x0B	smb://
0x0C	nfs://
0x0D	ftp://
0x0E	dav://
0x0F	news:
0x10	telnet://
0x11	imap:
0x12	rtsp://

```
0x13    urn:
0x14    pop:
0x15    sip:
0x16    sips:
0x17    tftp:
0x18    btspp://
0x19    btl2cap://
0x1A    btgoep://
0x1B    tcpobex://
0x1C    irdaobex://
0x1D    file://
0x1E    urn:epc:id:
0x1F    urn:epc:tag:
0x20    urn:epc:pat:
0x21    urn:epc:raw:
0x22    urn:epc:
0x23    urn:nfc:
```

Following the URI Identifier Code is the **URI Field**. This field provides the URI as per RFC 3987 and contains the rest of the URI after the value corresponding to the URI Identifier is prepended (unless the URI ID is 0x00, in which case the complete URI will be contained in the URI Field).

Test Records

To Do

Smart Poster Records

To Do

Example NDEF Records

Well Known Records

URI Record

An example of a URI record is shown in "Memory Dump of a Mifare Classic 1K Card with an NDEF Record" below.

Text Record
To Do

Smartposter Record
To Do

Absolute URI Record

To Do

Using Mifare Classic Cards as an NDEF Tag

Mifare Classic 1K and 4K cards can be configured as NFC Forum compatible NDEF tags, but they must be organised in a certain manner to do so. The requirements to make a Mifare Classic card "NFC Forum compliant" are described in the following App Note from NXP:

AN1304 - NFC Type MIFARE Classic Tag Operation (http://adafru.it/aSP)

While the App Note above is the authoritative source on the matter, the following notes may also offer a quick overview of the key concepts involved in using Mifare Classic cards as NFC Forum compatible 'NDEF' tags:

Mifare Application Directory (MAD)

In order to form a relationship between the sector-based memory of a Mifare Classic card and the individual NDEF records, the **Mifare Application Directory** (MAD) structure is used. The MAD indicates which sector(s) contains which NDEF record. The definitive source of information on the Mifare Application Directory is the following application note:

AN10787 - MIFARE Application Directory (MAD) (http://adafru.it/aSQ)

For reference sake, the two types of MADs (depending on the size of the card in question) are defined below:

Mifare Application Directory 1 (MAD1)

MAD1 can be used in any Mifare Classic card regardless of the size of the EEPROM, although if it is used with cards larger than 1KB only the first 1KB of memory will be accessible for NDEF records.

The MAD1 is stored in the Manufacturer Sector (Sector 0x00) on the Mifare Classic card.

Mifare Application Directory 2 (MAD2)

MAD2 can only be used on Mifare Classic cards with **more than 1KB of storage** (Mifare Classic 4K cards, etc.). It is **NOT** compatible with cards containing only 1KB of memory!

The MAD2 is stored in sectors 0x00 (the Manufacturer Sector) and 0x10.

MAD Sector Access

The sectors containing the MAD1 (0x00) and MAD2 (0x00 and 0x10) are protected with a KEY A and KEY B (if you're not familiar with this concept, consult the Mifare Classic summary elsewhere in the PN532/NFC wiki). To ensure that these sectors can be read by any application, the following common KEY A should always be used:

```
Public KEY A of MAD Sectors
-------------------------------------------------
BYTE 0   BYTE 1   BYTE 2   BYTE 3   BYTE 4   BYTE 5
0xA0     0xA1     0xA2     0xA3     0xA4     0xA5
```

The MAD sector may optionally be write-protected using KEY B if you wish to limit the ability of customers to modify the card contents. The public KEY A will ensure that they can always read the data.

Storing NDEF Messages in Mifare Sectors

NDEF messages/records may be stored in any sector of the Mifare card, other than the sector(s) use by the MAD or sectors beyond the 1K range if a MAD1 table is used.

When a sector is used to store NDEF records, it is referred to as an NFC Sector. As with the MAD Sector(s) described above, these sectors must always be accessible in at least read-only mode, and as such a common public KEY A also exists for NFC Sectors, though it is not the same KEY A used in the MAD sector(s):

```
Public KEY A of NFC Sectors
-------------------------------------------------
BYTE 0   BYTE 1   BYTE 2   BYTE 3   BYTE 4   BYTE 5
0xD3     0xF7     0xD3     0xF7     0xD3     0xF7
```

In order to store an NDEF Message on the Mifare Classic card, the message needs to be wrapped inside something called a **TLV Block**. The basic structure of a TLV Block is described below.

TLV Blocks

TLV is an abbreviation for three different fields: T for Tag Field, L for Length Field and V for Value Field. A TLV Block consist of one or more bytes, depending on which of these three fields is present. Note that the TLV Block will always be at least one byte since the T Field is mandatory in every case.

Tag Field

The Tag Field (or T Field) is the only mandatory field, and uses a single-byte to identify the type of TLV block accordingly to a pre-determined table of values:

```
TLV Block Types

 Block Type    Value  Description
 ------------ -----  ------------------------------------
 NULL          0x00   These blocks should be ignored
 NDEF Message  0x03   Block contains an NDEF message
 Proprietary   0xFD   Block contains proprietary information
 Terminator    0xFE   Last TLV block in the data area
```

Length Field

The Length Field (or L Field) contains the size (in bytes) of the value field. The Length Field can be organised in two different ways, using either one or three bytes.

The one byte format simple contains a single byte value from 0x00..0xFF.

The three byte format consists of the following format:

```
Byte 0:     Always 0xFF to indicate that we are using the three byte format
Byte 1..2:  Can be a value between 0x00FF and 0xFFFE
```

Both the one byte and three byte format must be supported for NFC Forum and NDEF compatability.

Value Field

The Value Field (or V Field) is only present if the Length Field (described above) is present and not equal to 0x00. If the Length Field is not equal to 0, the Value Fields will contain N bytes of data in the format indicated by the T Field above.

The value field is where the payload (an **NDEF Message**, for example) is stored.

Terminator TLV

The Terminator TLV is the last TLV block in the data area, and consist of a single byte: 0x0FE (see the TLV Block Type table above). This TLV Block in mandatory.

Memory Dump of a Mifare Classic 1K Card with an NDEF Record

```
[                    Start of Memory Dump                        ]
------------------------Sector 0-------------------------
Block 0  3E 39 AB 7F D3 88 04 00 47 41 16 57 4D 10 34 08  >9«□Ó?..GA.WM.4.
Block 1  14 01 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1  ...á.á.á.á.á.á.á
Block 2  03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1  .á.á.á.á.á.á.á.á
Block 3  00 00 00 00 00 00 78 77 88 C1 00 00 00 00 00 00  ......xw?Á......
------------------------Sector 1-------------------------
Block 4  00 00 03 11 D1 01 0D 55 01 61 64 61 66 72 75 69  ....Ñ..U.adafrui
Block 5  74 2E 63 6F 6D FE 00 00 00 00 00 00 00 00 00 00  t.comþ..........
Block 6  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 7  00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 2-------------------------
Block 8  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 9  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 10 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 11 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 3-------------------------
Block 12 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 13 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 14 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 15 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 4-------------------------
Block 16 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 17 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 18 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 19 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 5-------------------------
Block 20 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 21 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 22 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 23 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 6-------------------------
Block 24 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 25 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 26 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 27 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 7-------------------------
Block 28 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
```

```
Block 29 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 30 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 31 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 8-------------------------
Block 32 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 33 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 34 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 35 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 9-------------------------
Block 36 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 37 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 38 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 39 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 10------------------------
Block 40 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 41 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 42 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 43 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 11------------------------
Block 44 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 45 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 46 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 47 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 12------------------------
Block 48 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 49 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 50 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 51 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 13------------------------
Block 52 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 53 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 54 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 55 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 14------------------------
Block 56 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 57 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 58 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 59 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
------------------------Sector 15------------------------
Block 60 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 61 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 62 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
Block 63 00 00 00 00 00 00 7F 07 88 40 00 00 00 00 00 00  ......□.?@......
[                    End of Memory Dump                    ]
```

NDEF Records

The above example contains two records, both located in sector 1 (sector 0 contains the MAD).

Record 1

The first record on the card can be identified by looking at the first byte of block 4 in sector 1.

```
Block  00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15  Char Value
-----  ----------------------------------------------  ------------
04     00 00                                           ..
```

Every record on the Mifare card starts with the **TLV Block** (described above), and the first byte of the TLV Block (the Tag Field) indicates that this is a **NULL Block type (value 0x00)**. The second byte is the Length Field, and is 0. Since there is no payload for this record (Length = 0), the third byte of the TLV block is not present (the Value Field).

This record was likely inserted when the card was first formatted to ensure that at least one record is present.

Record 2

The second record on the card starts at byte 0x02 of block 4 and continues into block 5.

```
Block  00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15  Char Value
-----  ----------------------------------------------  ------------
04          03 11 D1 01 0D 55 01 61 64 61 66 72 75 69  Ñ..U.adafrui
05     74 2E 63 6F 6D                                  t.com
```

Starting with the **TLV Block** data in the first two bytes, we can determine the following:

```
Byte(s)   Value   Description
-------   -----   -----------
04:02     0x03    Field Type (0x03 = NDEF Message)
04:03     0x11    Length Field (17 bytes)
```

This indicates to us that the record contains an **NDEF Message** (value 0x03), and that the message is 17 bytes long (0x11 in hexadecimal = 17 in decimal value). This means that our NDEF message is contained in the next 17 bytes (04:04..05:04). The NDEF record can then be analysed as follows:

```
Byte(s)      Value  Description
-------      -----  -----------
```

```
04:04        0xD1   This byte is the **NDEF Record Header**, and indicates that this is
                    an NFC Forum Well Known Record (0x01 in the first 3 bits),
                    and that this is the first and last record (MB=1, ME=1),
                    and that this is a short record (SR = 1) meaning the payload
                    length is less than or equal to 255 chars (len=one byte).
                    TNF = 0x01 (NFC Forum Well Known Type)
                    IL  = 0    (No ID present, meaning there is no ID Length or ID Field either)
                    SR  = 1    (Short Record)
                    CF  = 0    (Record is not 'chunked')
                    ME  = 1    (End of message)
                    MB  = 1    (Beginning of message)
04:05        0x01   This byte is the **Type Length** for the Record Type Indicator
                    (see above for more information), which is 1 byte (0x55/'U' below)
04:06        0x0D   This is the payload length (13 bytes)
04:07        0x55   Record Type Indicator (0x55 or 'U' = URI Record)
04:08        0x01   This is the **start of the record payload**, which contains the
                    URI Identifier ("http://www.") since this is a URI Well-Defined
                    Record Type (see Well-Defined Records above).  This will be
                    prepended to the rest of the URI that follows in the rest of the
                    message payload
04:09..05:04 ...    The remainder of the URI ("adafruit.com"), which combined with the
                    pre-pended value from byte 04:08 yields: http://www.adafruit.com
```

TLV Terminator

```
Block  00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15  Char Value
-----  ----------------------------------------------  ------------
05                 FE                                  þ
```

The final byte (block 5, byte 5), with the value 0xFE, is the **TLV Terminator** and indicates that this is the end of the TLV Block.

Using with LibNFC

Using the PN532 Breakout Boards with libnfc

libnfc (http://adafru.it/aSR) is a mature, cross-platform, open-source NFC library that can be easily configured to work with the PN532 Breakout Board. While Linux is probably the easiest platform to use libnfc with, it can be configured for the Mac and Windows as well, though you may need to dig around on the libnfc Community Forums for some specific details on compiling .dlls for Windows, etc.

If you want to test the PN532 Breakout Board out with libnfc, this simple tutorial should walk you through the absolute basics of compiling and configuring libnfc, and using some of the canned example SW included in the library.

> This is only for using the PN532 breakout with an FTDI cable or FTDI Friend to a proper computer. You cannot run LIbNFC on an Arduino or other microcontroller

libnfc In Linux (Ubuntu 10.10 used in this example)

Step One: Download libnfc

Download the latest version of libnfc from Google Code (http://adafru.it/aSS) (ex. "libnfc-1.4.1.tar.gz") and extract the contents of the file as follows:

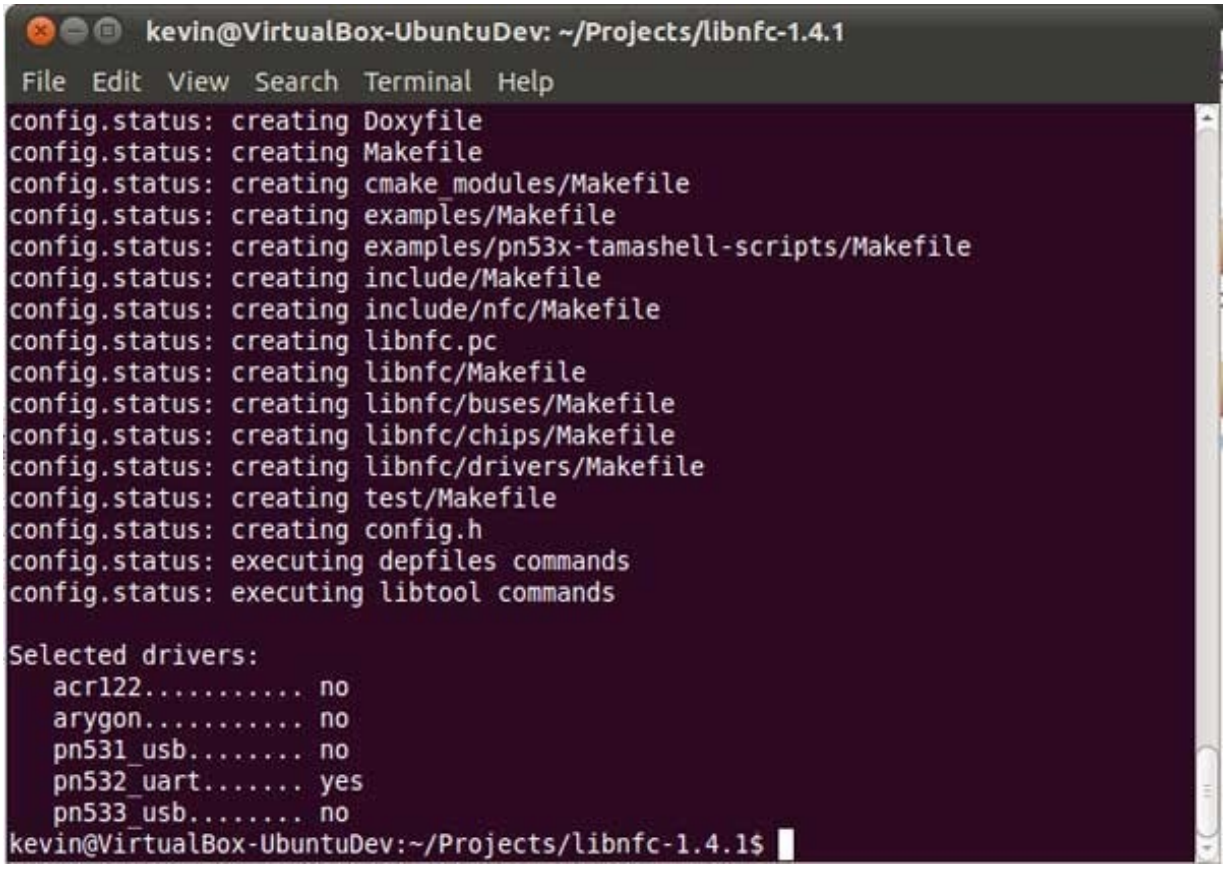
```
$ wget http://libnfc.googlecode.com/files/libnfc-x.x.x.tar.gz
$ tar -xvzf libnfc-x.x.x.tar.gz
$ cd libnfc-x.x.x
```

Step Two: Configure libnfc for PN532 and UART

libnfc currently only supports communication over UART, using any inexpensive USB to UART adapter like the FTDI Friend or a TTL FTDI cable. Before compiling, however, you will need to configure libnfc to include support for UART and the PN532 chipset, which can be done with the following commmand (executing in the folder where the above archive was unzipped):

```
$ ./configure --with-drivers=pn532_uart --enable-serial-autoprobe
```

Note: If you also wish to include debug output, you can add the '–enable-serial-autoprobe' flag (minus the single quotes) to the configure options



Step Three: Build and install libnfc

You can build and install libnfc with the following three commands, also run from the folder where the original archive was unzipped:

```
$ make clean
$ make
$ make install
```

Step Four: Check for installed devices

Now that libnfc is (hopefully) built and installed, you can run the 'nfc-list' example to try to detect an attached NFC board. Make sure the board is connected to the FTDI or USB/UART adapter, and that it is connected to your PC, and run the following commands:

```
$ cd examples
$ ./nfc-list
```

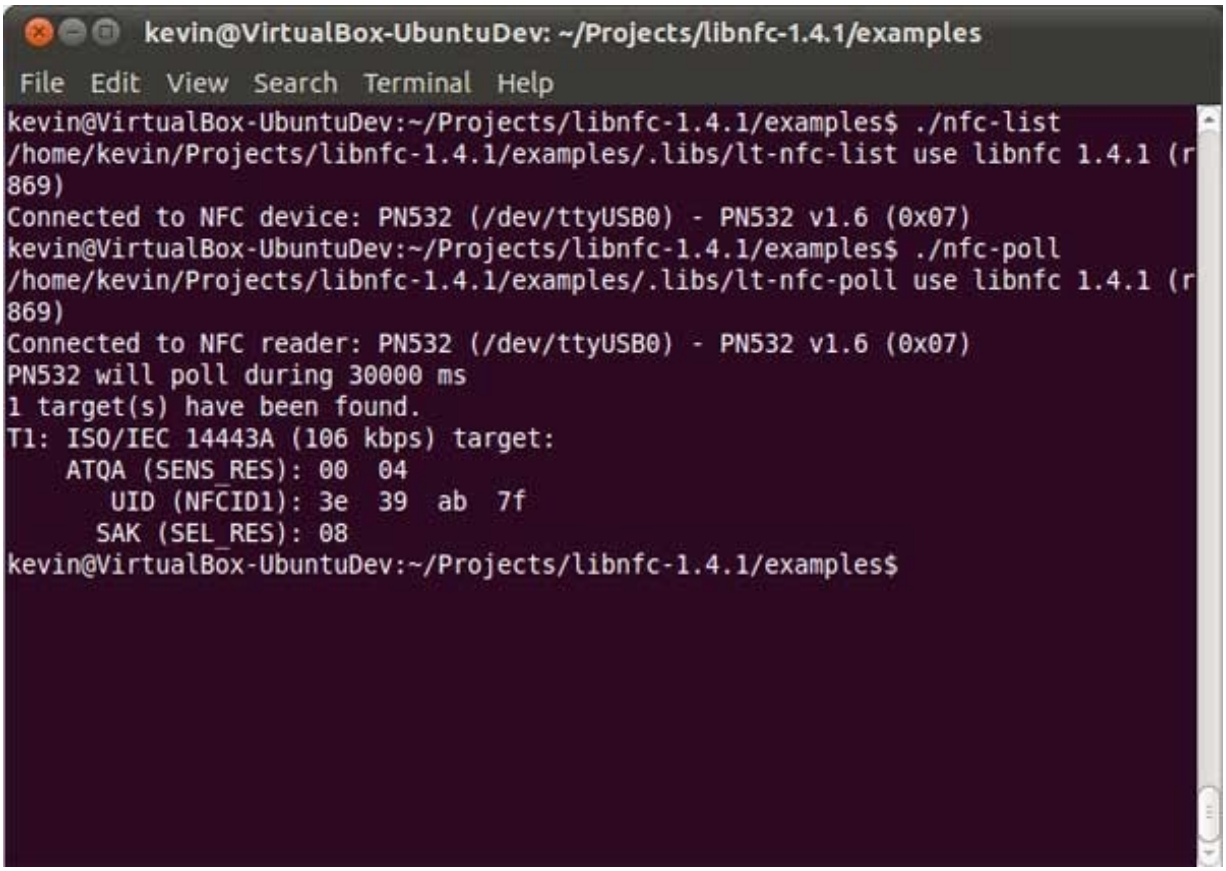
This should list the devices that were detected

Step Five: Poll for an ISO14443A (Mifare, etc.) Card

Next, you can use the 'nfc-poll' example to wait 30 seconds for an ISO14443A card or tag and display some basic information about this card. In the examples folder that we changed to above, run the following command:

```
$ ./nfc-poll
```

This should give you some basic information on any card that entered the magnetic field within the specified delay.


kevin@VirtualBox-UbuntuDev: ~/Projects/libnfc-1.4.1/examples
File Edit View Search Terminal Help
kevin@VirtualBox-UbuntuDev:~/Projects/libnfc-1.4.1/examples$ ./nfc-list
/home/kevin/Projects/libnfc-1.4.1/examples/.libs/lt-nfc-list use libnfc 1.4.1 (r
869)
Connected to NFC device: PN532 (/dev/ttyUSB0) - PN532 v1.6 (0x07)
kevin@VirtualBox-UbuntuDev:~/Projects/libnfc-1.4.1/examples$ ./nfc-poll
/home/kevin/Projects/libnfc-1.4.1/examples/.libs/lt-nfc-poll use libnfc 1.4.1 (r
869)
Connected to NFC reader: PN532 (/dev/ttyUSB0) - PN532 v1.6 (0x07)
PN532 will poll during 30000 ms
1 target(s) have been found.
T1: ISO/IEC 14443A (106 kbps) target:
ATQA (SENS_RES): 00 04
UID (NFCID1): 3e 39 ab 7f
SAK (SEL_RES): 08
kevin@VirtualBox-UbuntuDev:~/Projects/libnfc-1.4.1/examples$

libnfc With Mac OSX Lion

scott-42 was kind of enough to post some tips on getting libnfc working on a Mac using an FTDI adapter. A couple simple changes to the code were required (as of v1.6.0-rc1), with the details here (http://adafru.it/aP1).

Keeping in mind the code changes mentionned above, the following steps should get libnfc compiling and working via an FTDI type adapter and UART on Lion (using libnfc 1.6.0_rc1):

Download and build libnfc and configure if for PN532 UART (making the code changes above before running make):

```
wget http://libnfc.googlecode.com/files/libnfc-1.6.0-rc1.tar.gz
tar -xvzf libnfc-1.6.0-rc1.tar.gz
cd libnfc-1.6.0-rc1
./configure --with-drivers=pn532_uart --enable-serial-autoprobe
sudo make
sudo make install
```

If everything worked out, switch to the examples folder and see if you can find the PN532 and wait for an appropriate tag:

```
cd examples
Kevins-Mac-mini:examples kevin$ ./nfc-poll
/Users/kevin/libnfc-1.6.0-rc1/examples/.libs/nfc-poll uses libnfc 1.6.0-rc1 (r1326)
NFC reader: pn532_uart:/dev/tty.usbserial-FTE5WWPB - PN532 v1.6 (0x07) opened
NFC device will poll during 30000 ms (20 pollings of 300 ms for 5 modulations)
ISO/IEC 14443A (106 kbps) target:
    ATQA (SENS_RES): 00  04
       UID (NFCID1): 3e  b9  6e  66
      SAK (SEL_RES): 08
```

There are some dependencies to get libnfc running, but since it isn't an Adafruit project and we can't really support it directly ourselves, you will probably have better luck looking at the libnfc forums (http://adafru.it/aST) for Mac support. There are a few active users developping on the Mac.

FAQ

Some of the more common questions on the forums related to the PN532 NFC/RFID Breakout (http://adafru.it/364) and NFC Shield (http://adafru.it/789).

Can I have multiple shields on one Arduino?
Nope, the I2C library can have only one address per bus and the address is not adjustable! So one shield per Arduino please!

Can I read or write to Mifare tags with the PN532 and Adafruit Libraries?
Absolutely! The Adafruit libraries include functions to authenticate, read and write individual blocks to Mifare Classic cards. Before you can read or write a block you need to authenticate it with the appropriate key, and once the block is authenticated you can read and write to your hearts content)!

For example, the key functions in the I2C library (http://adafru.it/aSW) (which was written to go along with the NFC shield (http://adafru.it/789) since it defaults to I2C) are:

```
uint8_t mifareclassic_AuthenticateBlock (uint8_t * uid, uint8_t uidLen,
                                         uint32_t blockNumber, uint8_t keyNumber,
                                         uint8_t * keyData);
uint8_t mifareclassic_ReadDataBlock (uint8_t blockNumber, uint8_t * data);
uint8_t mifareclassic_WriteDataBlock (uint8_t blockNumber, uint8_t * data);
```

This is all you need to start reading and writing data, and you can verify the data using one of many Android applications that support working with Mifare cards (a search for NFC will turn up plenty).

What level of NDEF support is included in the libraries?
At the moment, all NDEF (http://adafru.it/aXr) features are experimental and incomplete. Only very basic test code has been written to format a card for NDEF messages in a way that any NFC-enabled Android phone should be able to understand it, and it was written and an extremely simple proof of concept.

We would like to improve NDEF support for Mifare tags in the near future and some initial planning has gone into this, but at the moment our suggestion is to stick to plain text and 'vanilla' Mifare Classic (http://adafru.it/aXs) reads and writes. You can read and write Mifare Classic and Mifare Ultralight blocks from Android, and you don't need to used the more complicated NDEF standard to simply pass data back and forth via a Mifare Classic or Ultralight card.

Note: Please use the limited NDEF code with care. Formatting cards for NDEF support is currently a one way operation, and should only be performed on cards you can dedicate to NDEF use.

Does the PN532 support peer to peer communication to talk with my smartphone?
Yes, the PN532 supports peer to peer communication, but the SW support for this isn't implemented in the Adafruit libraries.

Peer to peer communication with Android is possible, for example, but the actual implementation is quite complicated on the PN532 side. You need to go through a lot of SW layers to communicate with Android in a way that it understands -- it would require developing a full NDEF stack for the messages, SNEP and LLCP stacks, etc. -- which is unfortunately well beyond the scope of what we can offer on a development board at this price point.

All of the HW requirements for this are met with the Adafruit shield and breakout board, but the stack implementation is non trivial and would require us to charge a significant premium for these boards if we implemented this.

We've focused our energy on providing a reliable, proven, properly-tuned HW reference, and enough of a SW building block to get everyone started, but there are too many holes to fill in to cover everything NFC can do with a development board at this price point.

For an example of communicating with a phone via NFC, though, have a look at "Talking With Your Arduino via NFC on Blackberry (http://adafru.it/aXt)" which uses the Adafruit NFC Shield. The SW layers required for NFC-based P2P communication with a Blackberry device are apparently much lower than on Android.

Does the PN532 support tag emulation?
Yes, but in reality it's impossible to implement since it requires an external 'secure element (http://adafru.it/aXu)' that is very difficult to source (under export control and general NDA from the few manufacturers of them). If you can get one we'd love to see it, though!

Can the PN532 read Tag-It tags from TI?
No. The PN532 is designed to be used with ISO14443 (http://adafru.it/aSU) tags, with Mifare Classic probably the most common general-purpose tag type in use. For more information on supported tags seehttp://www.libnfc.org/documentation/hardware/tags/iso14443 (http://adafru.it/aSV) or search for information on the common Mifare tag family based on ISO1443A.

Can I set a delay calling readPassiveTargetID()?
Note: This question only applies to the I2C Library (http://adafru.it/aSW). The SPI library (http://adafru.it/aSX) doesn't handle the timing the same way.

readPassiveTargetID() intentionally waits around in a blocking delay until a card enters the magnetic field. The reason for this blocking delay is to ensure a well-understood command/response flow. Once the magnetic field is activated and a read request is sent via readPassiveTargetID, you can keep sending new commands to the PN532, but the

moment a card or tag enters the field, the PN532 will send a response to the initial read request, even if it's in the middle of some other response or activity. To avoid having to debug this in SW, a blocking delay was implemented to keep the command/response pattern as clear as possible.

As a workaround to this blocking-delay limitation, **setPassiveActivationRetries(maxRetries)** was added to the latest NFC libraries to allow you to set a specific timeout after read requests.

By default, the PN532 will wait forever for a card to enter the field. By specifying a fixed number of retries via **MxRtyPassiveActivation** (see UM section 7.3.1 describing the **RFConfiguration** register, specifically CfgItem 5) the PN532 will abort the read request after specified number of attempts, and you can safely send new commands without worrying about mixing up response frames. To wait forever, set MxRtyPassiveActivation to 0xFF. To timeout after a fixed number of retries, set MxRtyPassiveActivation to anything less than 0xFF.

Example Sketch:

```
#include <Wire.h>
#include <Adafruit_NFCShield_I2C.h>

#define IRQ   (2)
#define RESET (3)  // Not connected by default on the NFC Shield

Adafruit_NFCShield_I2C nfc(IRQ, RESET);

void setup(void) {
  Serial.begin(115200);
  Serial.println("Hello!");

  nfc.begin();

  uint32_t versiondata = nfc.getFirmwareVersion();
  if (! versiondata) {
    Serial.print("Didn't find PN53x board");
    while (1); // halt
  }

  // Got ok data, print it out!
  Serial.print("Found chip PN5"); Serial.println((versiondata>>24) & 0xFF, HEX);
  Serial.print("Firmware ver. "); Serial.print((versiondata>>16) & 0xFF, DEC);
  Serial.print('.'); Serial.println((versiondata>>8) & 0xFF, DEC);

  // Set the max number of retry attempts to read from a card
  // This prevents us from waiting forever for a card, which is
```

```
  // the default behaviour of the PN532.
  nfc.setPassiveActivationRetries(0xFF);

  // configure board to read RFID tags
  nfc.SAMConfig();

  Serial.println("Waiting for an ISO14443A card");
}

void loop(void) {
  boolean success;
  uint8_t uid[] = { 0, 0, 0, 0, 0, 0, 0 };  // Buffer to store the returned UID
  uint8_t uidLength;                        // Length of the UID (4 or 7 bytes depending on ISO14443A card typ

  // Wait for an ISO14443A type cards (Mifare, etc.).  When one is found
  // 'uid' will be populated with the UID, and uidLength will indicate
  // if the uid is 4 bytes (Mifare Classic) or 7 bytes (Mifare Ultralight)
  success = nfc.readPassiveTargetID(PN532_MIFARE_ISO14443A, &uid[0], &uidLength);

  if (success) {
    Serial.println("Found a card!");
    Serial.print("UID Length: ");Serial.print(uidLength, DEC);Serial.println(" bytes");
    Serial.print("UID Value: ");
    for (uint8_t i=0; i < uidLength; i++)
    {
      Serial.print(" 0x");Serial.print(uid[i], HEX);
    }
    Serial.println("");
    // Wait 1 second before continuing
    delay(1000);
  }
  else
  {
    // PN532 probably timed out waiting for a card
    Serial.println("Timed out waiting for a card");
  }
}
```

Hey wait ... isn't there something funny with the SVDD pin?

Indeed, good eye! Unfortunately, both v1.0 and v1.3 of the breakout boards have a problem on the schematic. SVDD is connected directly to VDD, but should be left floating since it is used to power secure modules. This has no effect on the functionality of the boards, but does cause some extra current to be drawn. It will be fixed on the next revision of the board, but if you require the use of the secure modules (rare), you can simply cut the trace to the left of C22, which is the cap connected to SVDD (just follow

the trace straight up from pin 37).

Are there any special requirements to use the PN532 Breakout with the Due?
While the libraries do not officially support the Due yet, some customers have been able to get them working with some minor changes to the library.

We recommend using the I2C libraries with both the shield and the breakout boards since the I2C library represents the latest code from Adafruit, and the shield version should work without too much effort.

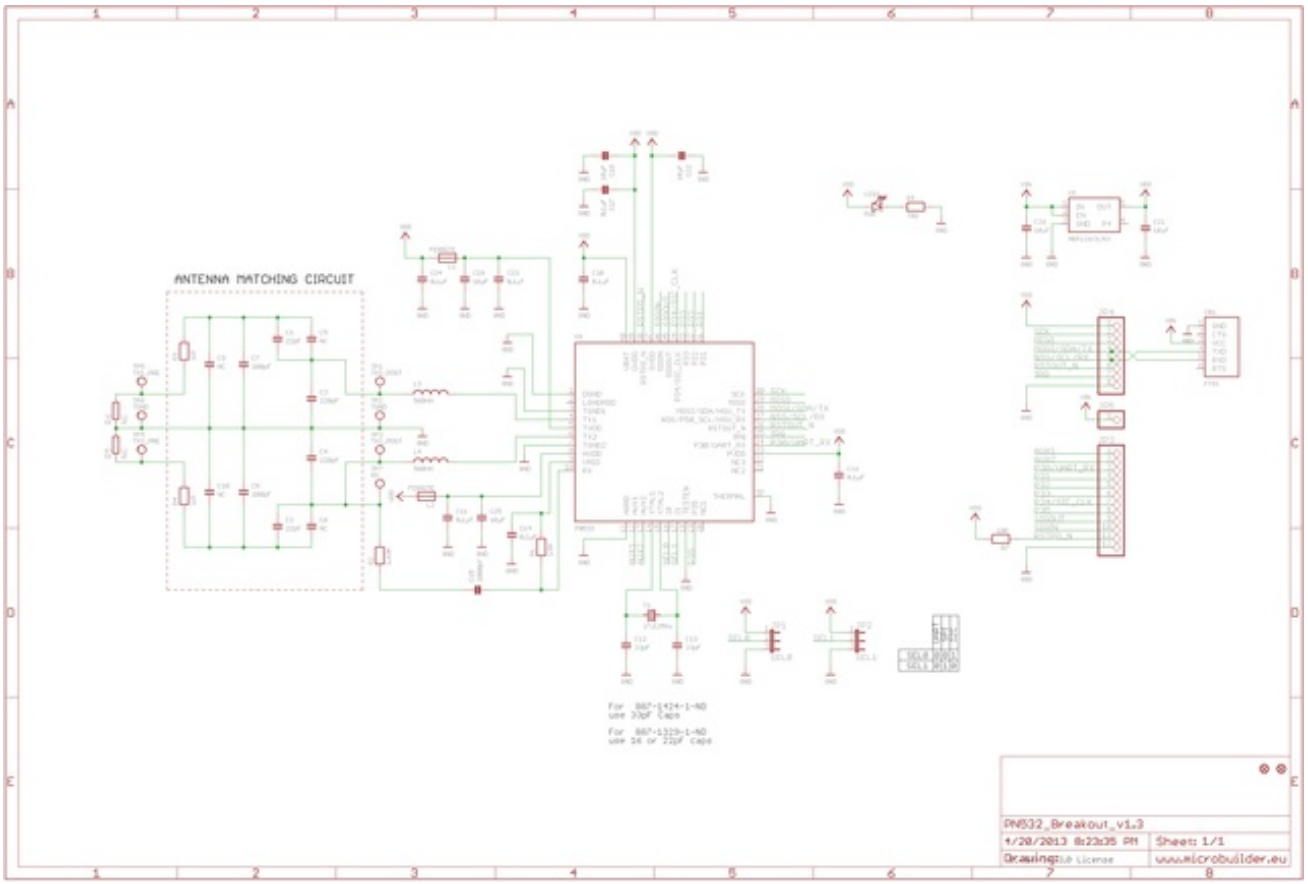
There is one caveat combining the breakout, I2C and the Due, though: **The Due includes pullup resistors for I2C0 (SCL0 and SDA1), but there are no pullups resistors on SCL1 and SDA1**. SCL1/SDA1 are the pins used as replacements for the Uno I2C pins (the pins used on standard shields), so you will need to add two 1.5K pullups on SCL1 and SDA1 to use the breakout board with I2C1 and the Due. Simply solder two 1.5K resistors, one from SCL1 to 3V3 and another from SDA1 to 3.3V, and then connect the board the same way you would with an Uno.

This issue only applies to the PN532 Breakout board since the PN532 shield includes I2C pullup resistors right on board.

Downloads

- SPI library is available from github (http://adafru.it/aSX)
- I2C library is available from github (http://adafru.it/aSW)

Version 1.3 schematic (click to enlarge)



PN532 Breakout v1 Schematic

http://adafru.it/d7l

You can also grab the Eagle CAD PCB files from github:

- https://github.com/adafruit/Adafruit-PN532-RFID-NFC-Shield (http://adafru.it/dik)
- https://github.com/adafruit/Adafruit-PN532-RFID-NFC-Breakout (http://adafru.it/dil)